



NAS Strategy Simulator– Fleet Mix Module

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Outline

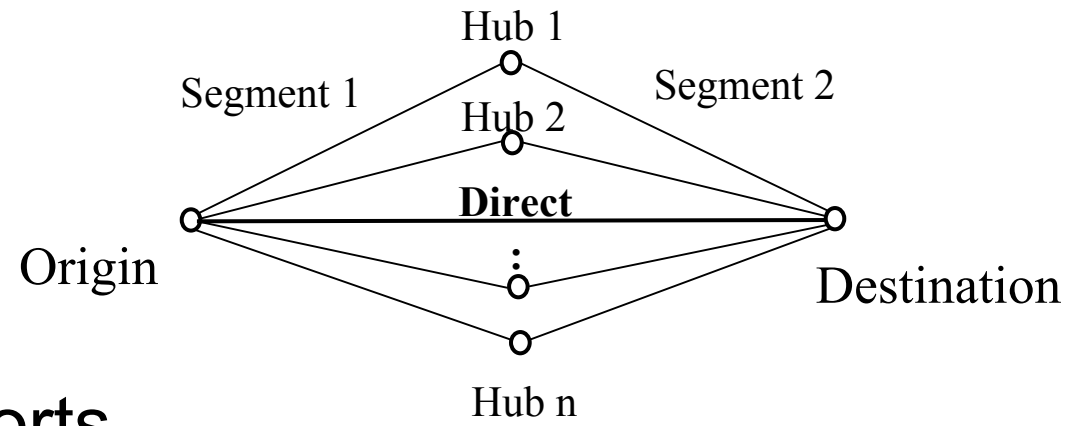
- The Problem
- Approaches
 - Framework
 - Four models
 - ✓ Equilibrium Flow Model
 - ✓ Load Factor Model
 - ✓ Aircraft Size Model
 - ✓ Fleet Mix Model
- Future Research



Problem



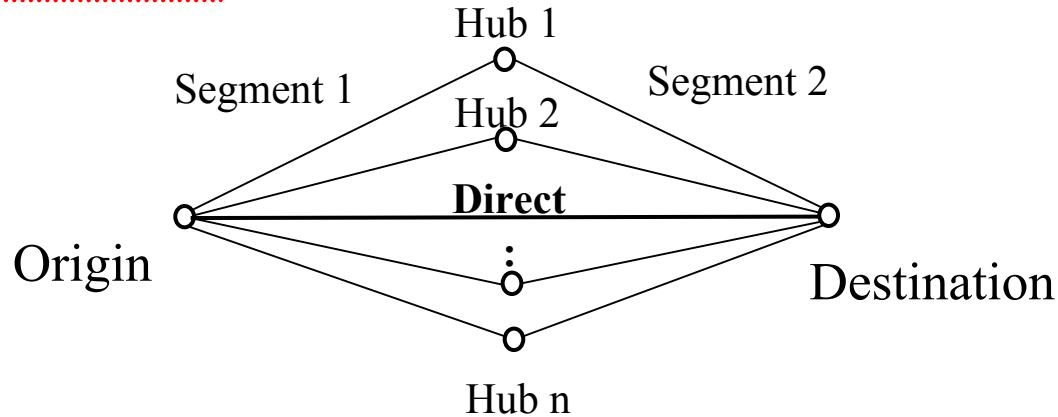
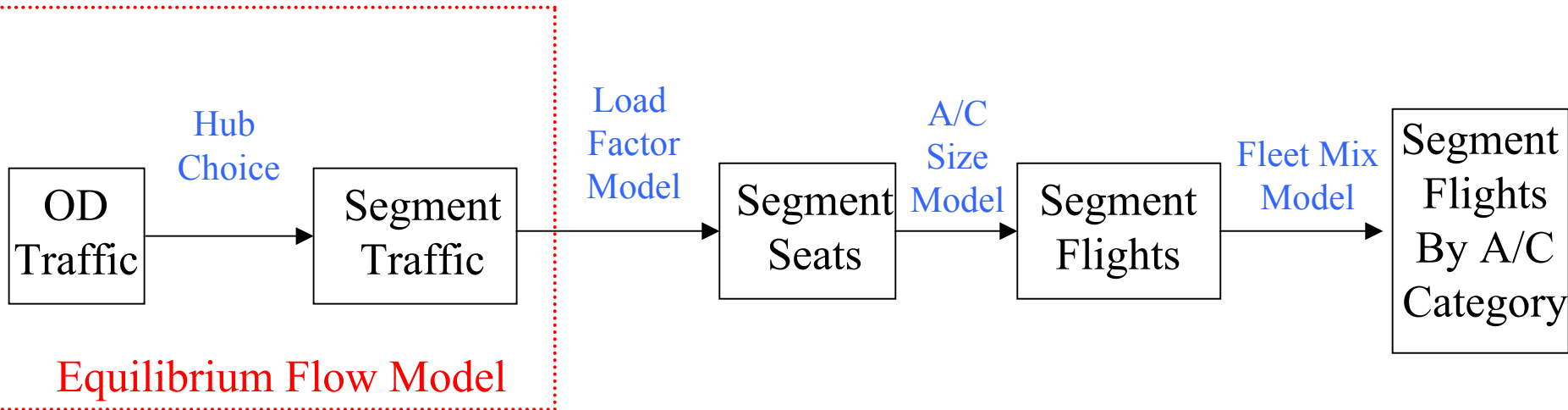
- ❑ Given the OD demand, predict
 - Segment traffic
 - Fleet mix



- ❑ Scope: 31 Benchmark Airports

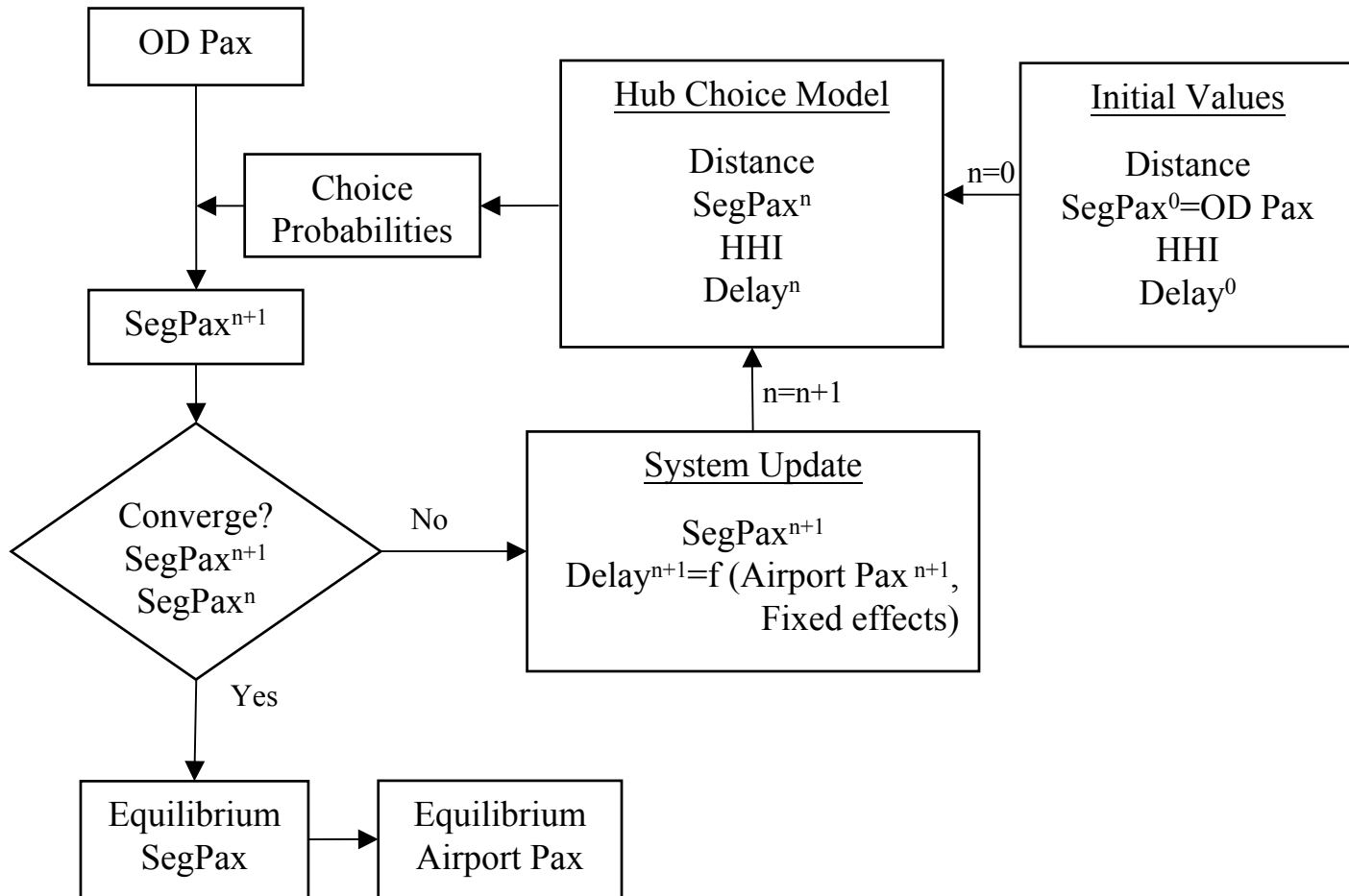


Framework





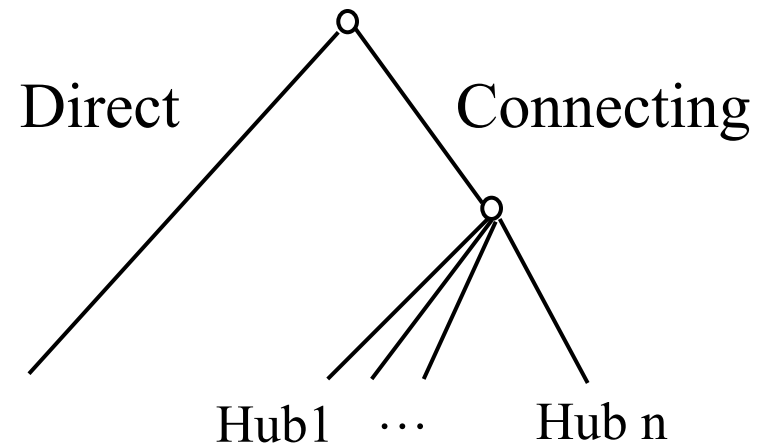
Equilibrium Flow Model





Hub Choice Model

- ❑ Allocates OD Traffic to Segment Traffic—
Route (hub) Choice
- ❑ Nested Logit Model
 - Direct or one-stop connecting
 - Conditioned on connecting, choose the connecting airport(hub)





Model Specification

$$P_{od}(Direct) = \frac{\exp(V_{direct})}{\exp(V_{direct}) + (\sum_i \exp(\beta V_{od,i}))^{1/\beta}}; P_{od}(Hub:i | Connect) = \frac{\exp(V_{od,i})}{\sum_i \exp(V_{od,i})}$$

$$V_{direct} = c_0 + b_{01} \ln(distD_{od}) + b_{02} \ln(paxD_{od}) + b_{03} \ln(HHI_{od})$$

$$V_{od,i} = b_1 \ln(distC_{o-i-d}) + b_2 \ln(\max pax_{oi/di}) + b_3 \ln(\min pax_{oi/di}) + b_4 \ln(Delay_i)$$

- distD/ distC : direct /connecting (O-hub-D) distance between OD
- paxD: # of pax of the direct segment
- maxpax: # of pax of the higher traffic segment
- minpax: # of pax of the lower traffic segment
- HHI: Herfindahl-Hirschman Index (0 to 1) of the direct segment od
- delay: the delay (the number of delayed operations per 1000 operations) of connecting airport i



Model Estimation

Associated Factor	Estimate Parameter	Standard Error (*10 ⁻⁴)	P-value
ln(Dist. of Connect)	-2.929	0.984	[.000]
ln(Max Pax of Connect)	0.226	0.179	[.000]
ln(Min Pax of Connect)	0.665	0.201	[.000]
ln(Delay of Connect)	-0.073	0.063	[.000]
β , 1/(inclusive value)	1.453	0.399	[.000]
Constant of Direct	2.386	2.295	[.000]
ln(Dist. of Direct)	-3.027	0.847	[.000]
ln(Seg. Pax of Direct)	0.986	0.127	[.000]
ln(HHI of Direct)	-0.272	0.294	[.000]

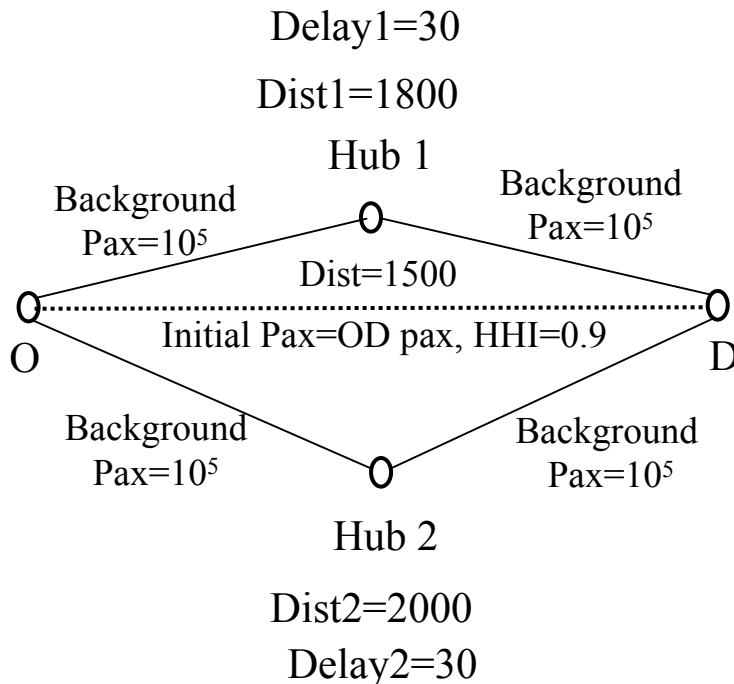
$$\hat{\rho}^2 = 0.5555$$

N=39,298,503 (100,951 routes)



Equilibrium Flow Example

- Segment and OD density, and delay effects (segment pax are endogenous)

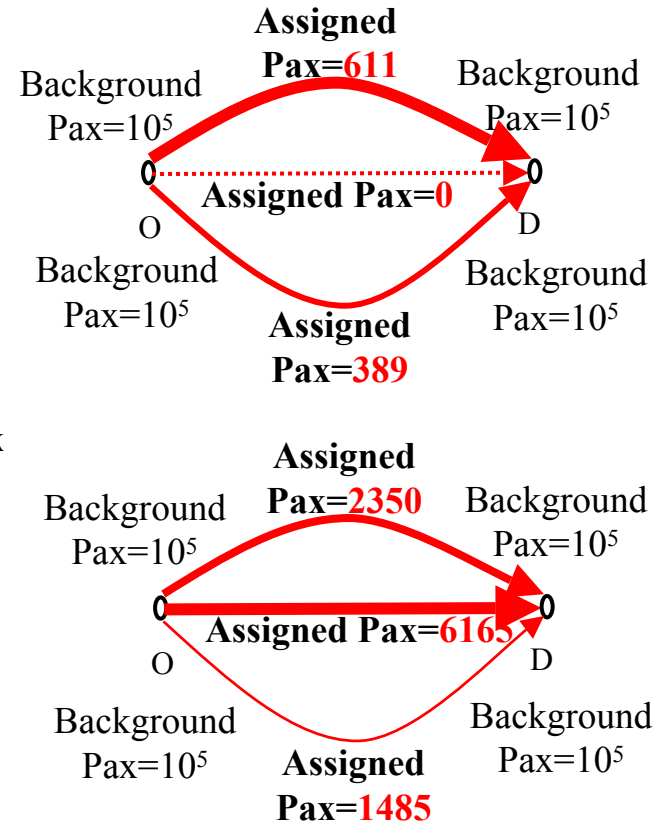


Equilibrium
(After 7 iterations)

1,000 OD pax

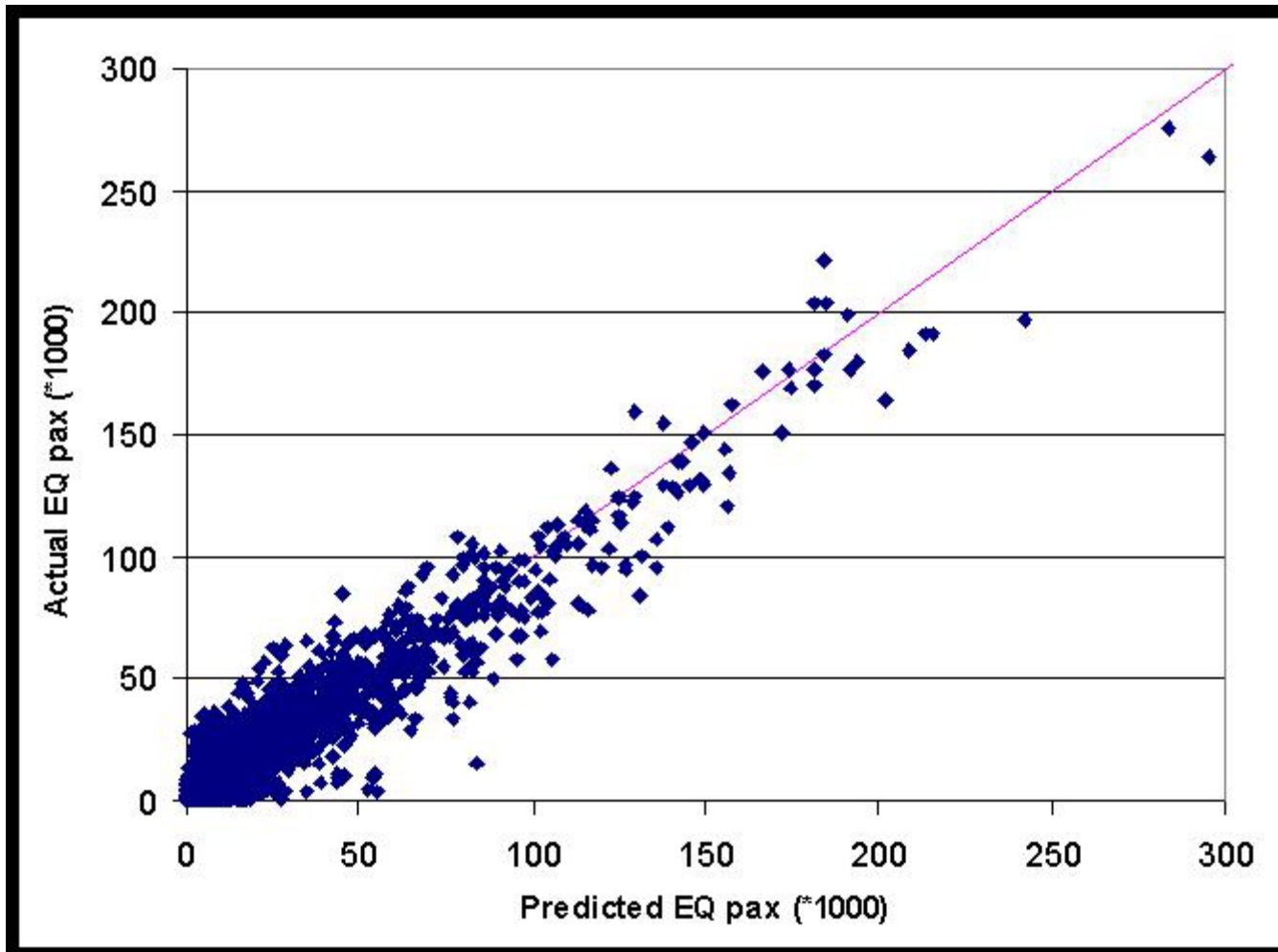
10,000 OD pax

Equilibrium
(After 10 iterations)



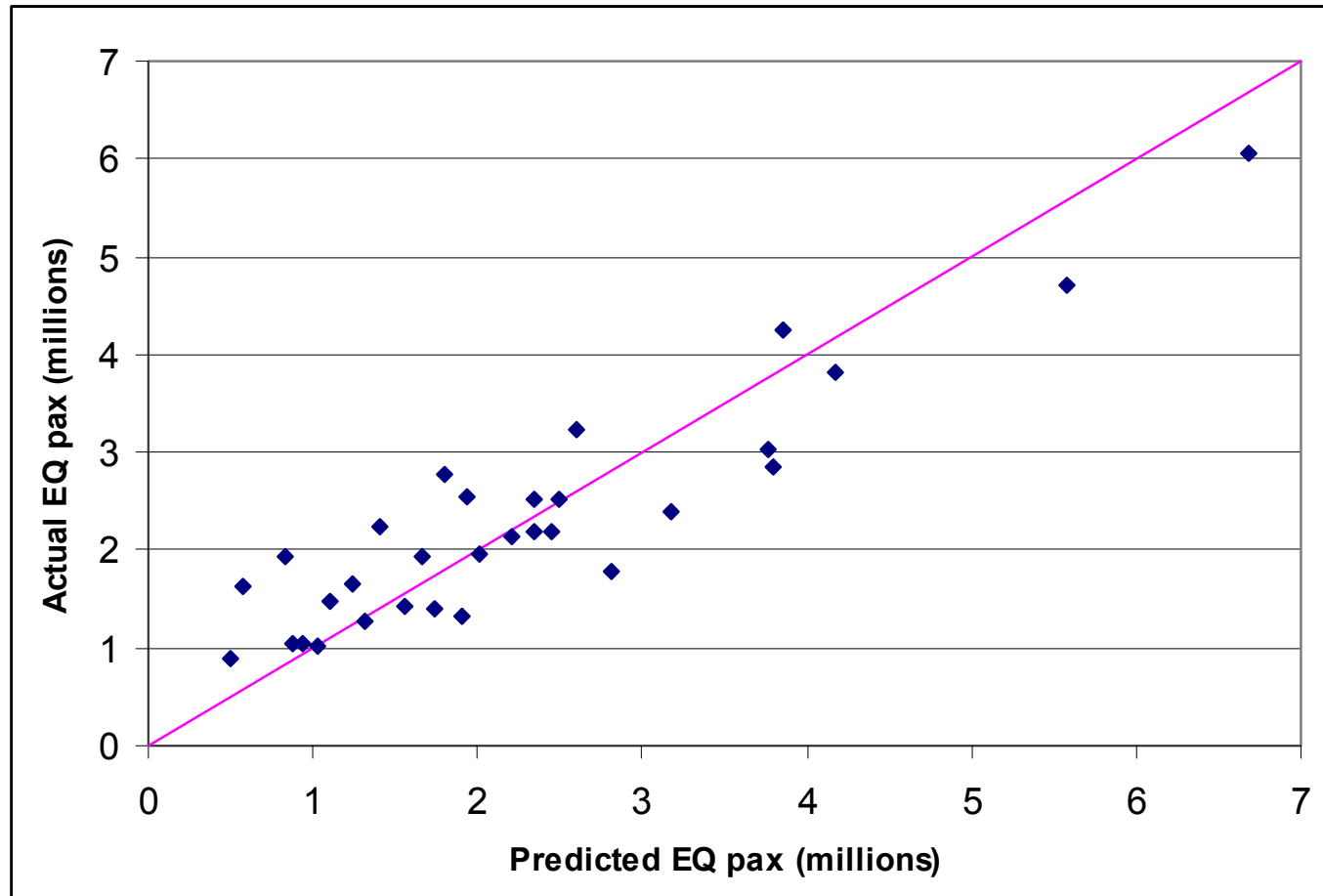


NAS Equilibrium- Segment Level





NAS Equilibrium- Airport Level



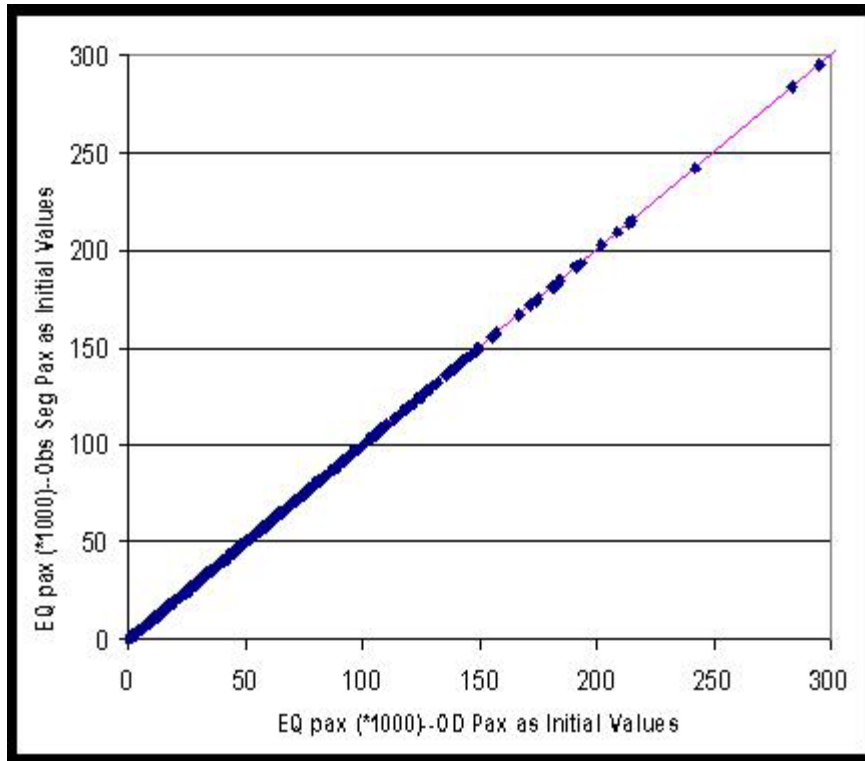


Equilibrium Prediction

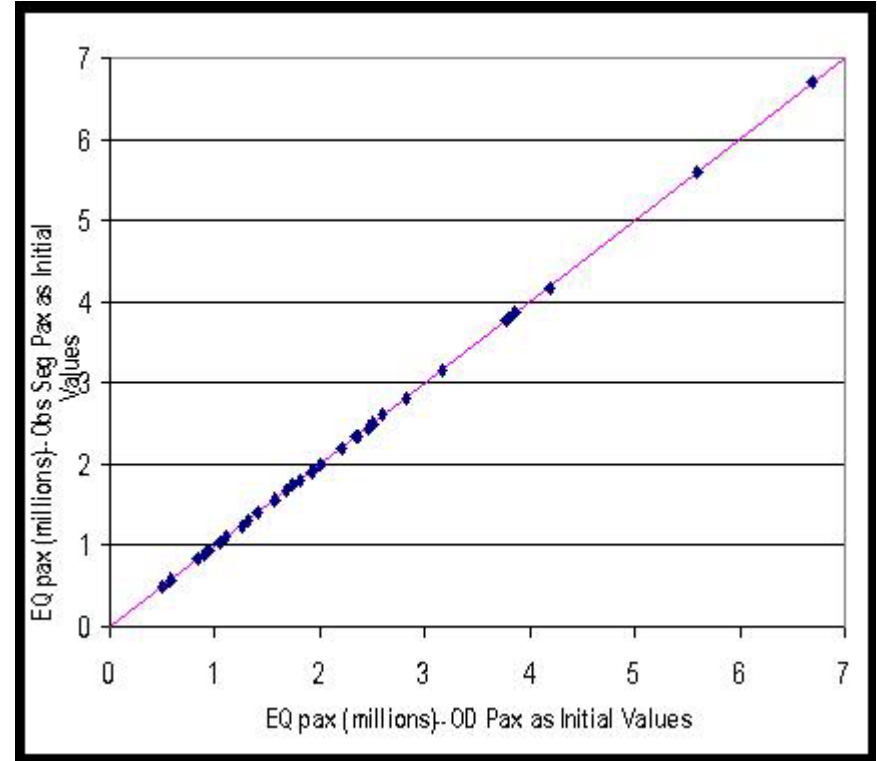
- Possible situations:
 - Multiple Equilibria
 - May depend on the initial values and convergence criteria
 - Some equilibria may differ from the current status



Equilibria- initial values



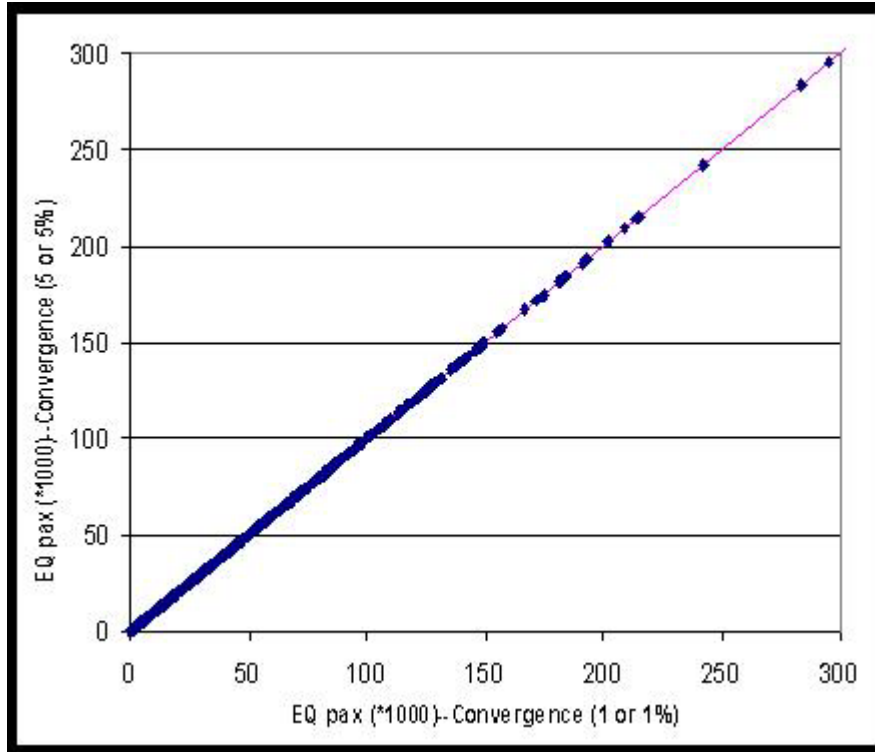
Segment Level



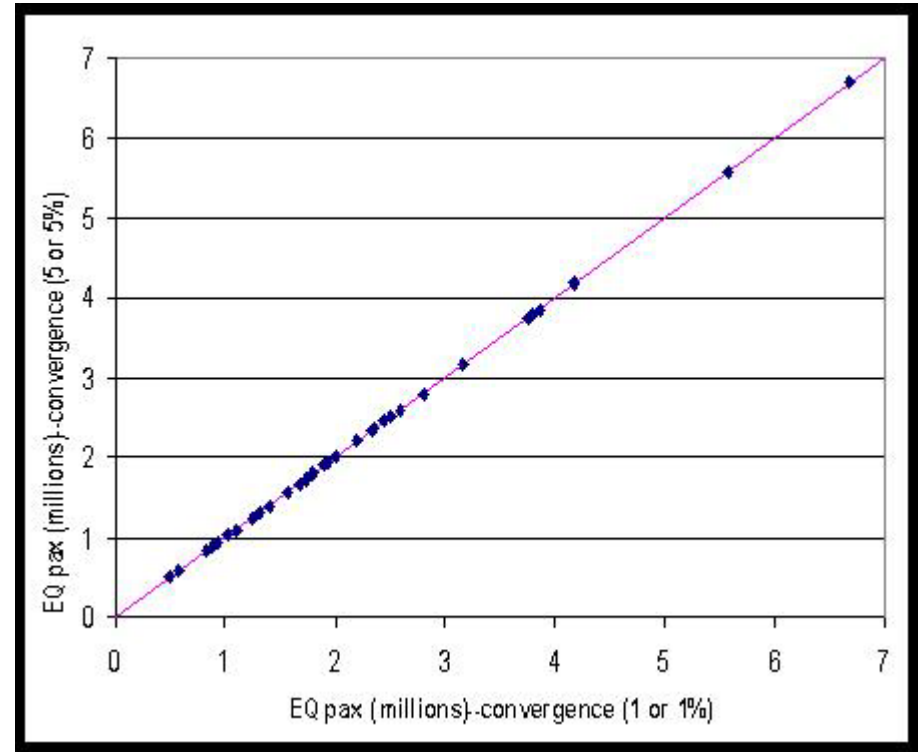
Airport Level



Equilibria- Convergence Rules



Segment Level



Airport Level



Policy Experiment— ORD Delay Improvement

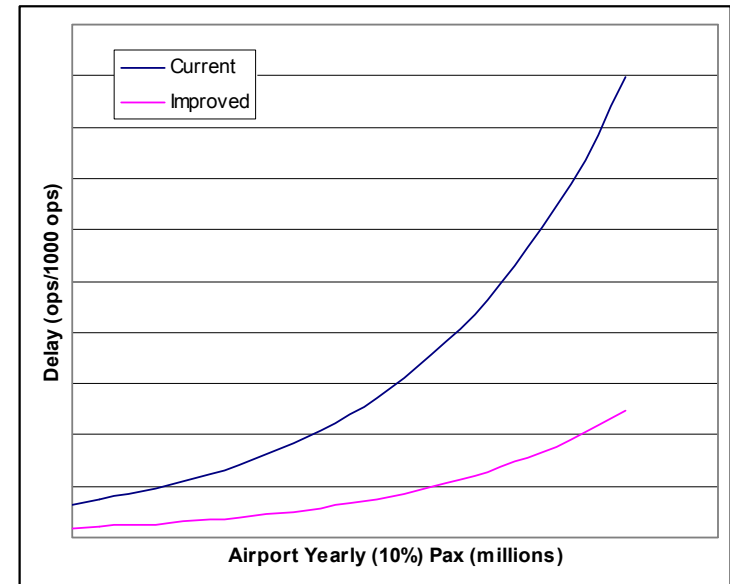
□ Delay:

$$\ln(\text{Delay}_{it}) = \alpha_0 + \sum_{i=1}^{30} \alpha_i * C_i + \beta_1 * \text{Pax}_{it} + \varepsilon_{it}$$

□ Airport fixed delay effect improved:

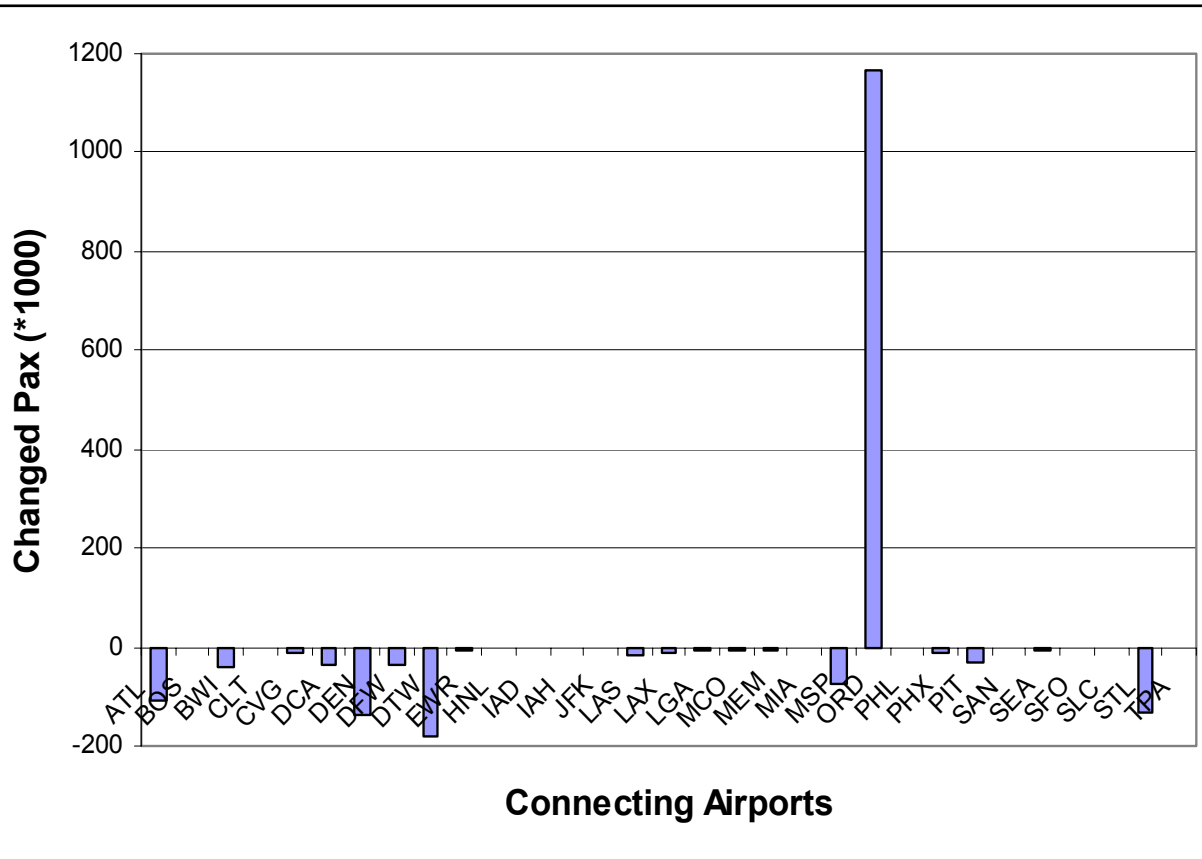
$$\alpha_{ORD} = 1.70542 \rightarrow$$

$$\alpha_{ORD}' = \alpha_{DEN} = 0.42284$$





Policy Experiment— New Equilibrium Results



- ORD: +1,164,665
- Other hubs: -876,506
- Net effect on the system: +288,159
- ORD attracts:
 - ¾ from competing hubs
 - ¼ from “direct” routes



Conclusions—Hub Choice Model

□ Conclusions

- The equilibrium model reflects the economics of the route choice
- Conserves OD traffic at airport level while allowing connecting traffic to vary
- A tool for policy analysis



Future works (1/2)

- Model Structure (Better Equilibrium Estimation)
 - Positive Feedback system
 - Dynamics of the system
 - Travelers' behavior: flexible model form & Endogeneity
 - Computation efficiency



Future works (2/2)

- Affecting Factors Modeling
 - Delay
 - Market Concentration (HHI)
 - Other factors, for example, airport capacity
- System-wide Effects Estimation
 - Better Policy Analysis Tool



Questions?